Paper Number: 5417

U-Pb age for the Ongeluk Basalts: implications for GOE and global glaciations

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The Transvaal Basin of southern Africa (ca. 2.65-2.06 Ga) comprises one of the best-preserved and most complete stratigraphic records spanning a critical interval in Earth history, an interval that saw growth and progressive emergence of the first large continents, the first significant rise in atmospheric oxygen levels (Great Oxidation Event, GOE), global ice ages and, finally, one of the largest seawater carbon isotopic excursions. Since du Toit's early synthesis of South African geology [1], a key correlation line for interpreting the Transvaal stratigraphy has been to equate the two main basaltic formations, the mostly submarine Ongeluk Basalts in the Griqualand West sub-basin and the subaerial Hekpoort Basalts in the main Transvaal sub-basin. Based on Rb/Sr and Pb/Pb data (isochrons) these basalt formations have long been considered to be ca. 2.22 Ga in age, specifically 2222 ±13 Ma for the Ongeluk Basalts [2]. Fine-grained basalts remain difficult targets to date and experience has shown that Pb/Pb isochrons are easily reset, typically yielding ages that are too young. Modern instrumental techniques, combining the search capabilities of electron microscopes and the high spatial resolution, *in-situ* U-Pb dating capabilities of ion probes, can overcome these difficulties by dating small, but otherwise well-preserved "micro-baddeleyites" [3]. Using these techniques, in conjunction with ID-TIMS dating of coarser-grained dolerite feeders, we have dated the Ongeluk Basalts at ca. 2426 Ma [4]. As the Ongeluk Basalts overlie and interfinger with the glacial Makganyene diamictites, and straddle the onset of GOE, our new age also dates the termination of the first of four [5] Paleoproterozoic glaciations and the onset of GOE. Previous work has shown that the Ongeluk Basalts erupted at low latitude [6], a key observation re-confirmed by our study and implying that the Makganyene glacial event was likely global, i.e. a "snowball glaciation". The new Ongeluk Basalt age, in conjunction with other critical observations, forces a reinterpretation of the Transvaal Basin stratigraphy. We propose that the Postmasburg Group of the Griqualand West sub-basin is entirely older than the upper part of the Transvaal sub-basin, i.e. older than the Duitschland Formation and Lower Pretoria Group. If the Makganyene, Ongeluk, and overlying Hotazel and Mooidraai formations (Postmasburg Group) ever extended into the Transvaal sub-basin, their record has been erased by erosion below the base of the Duitschland Formation, which is marked by a significant angular unconformity that represents the demise, folding, and subsequent uplift of the of the Ghaap and Chuniespoort Group depositional system. Following this main tectonic disturbance, there was a shift in depocentre to the northeast and initiation of a lithologically different (successor?) basin represented by the Duitschland Formation and the unconformably overlying Pretoria Group. Combining this new stratigraphic framework with the published record of redox indicators suggests that the onset of GOE was not characterized by a single transition and monotonic rise of atmospheric oxygen levels but rather by one or more "oscillations" in oxygen levels before final irreversible oxygenation of the atmosphere and the first appearance of red-bed sandstones. Our new Ongeluk Basalt age eliminates the >200 Myr hiatus below the Makganyene diamictites and argues for an essentially continuous depositional record leading up to the Makganyene snowball glaciation. This leads

us to interpret the Makganyene glaciation as the first Paleoproterozoic glaciation and we correlate it with the Ramsay Lake Formation of the Huronian Supergroup. Cap carbonates are lacking above this first glaciation. We correlate the Lower Duitschland glaciation with the Bruce glaciation, identifying it as the second global glaciation. It is overlain in both basins by a unique level of cap carbonates of potentially global significance.

References:

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